The Antibacterial Properties of Some Plants Found in Hawaii

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Many of the plants, both indigenous and introduced, which now grow in Hawaii have been used for medicinal purposes by the native Hawaiians and by the people of other countries who have come to live in Hawaii. When, in 1934, Handy, Pukui, and Livermore made their survey of the Hawaiian pharmacopeia, they were able to distinguish 317 different botanical components in the catalogue of ingredients used until that time. It is probable that many other species of plants which are sources of favorite remedies in other countries have been imported to Hawaii and could be added to the list prepared by Handy and his coworkers (1934), who were concerned primarily with remedies used by the native Hawaiians.

The Hawaiian remedies, especially those derived from the lore of the *kahuna lapaau laau,* the herb doctor of the ancient Hawaiians, have been much praised but they have never been critically appraised; and we thought that perhaps we could gain some idea of their relative value if we studied the medicinal plants from which these remedies were prepared for evidences of the antibacterial properties they might possess.

Most of the plants we set out to study were chosen from the native Hawaiian *materia medica,* but we did not exclude plants used for medicinal purposes by people of other ethnic groups. In some instances, moreover, we studied imported plants which were related to the species considered to be of value by the Hawaiians, even though the imported plants were not themselves mentioned in the accounts we consulted in preparing our own list of plants to be investigated.

Our list was compiled from several publications discussing Hawaiian pharmaceutics (Kaaiakamanu and Akina, 1922; Degener, 1930; Handy, Pukui, and Livermore, 1934; Neal, 1948); from suggestions given us by a Hawaiian herbalist on plants in current usage; and from hearsay and our own personal experience with plants used by Japanese, Chinese, and other ethnic groups in Hawaii. In preparing this list, those plants which appear to have been used against bacterial infections were selected wherever identification of the plant had been established and whenever it was likely that we would be able to find it in order to test it. The more common or the more famous of the medicinal plants were also included in the list, even if they had been employed to treat conditions obviously having no bacterial etiology. Our list, then, is a heterogeneous one, by no means confined to the native Hawaiian plants, and contains more than 275 entries.

When we began these studies we expected to be able, in time, to study all the plants in our list, and therefore were not particularly concerned about the order in which we collected them, taking them in the haphazard sequence in which we found them; but now the pressure of other duties makes it evident that we shall not be able to finish the studies as we had planned. Rather than lose the information we have obtained, therefore, we are recording in this paper the data from our observations on the 101 medicinal plants we were able to investigate before our studies were forced to an end.

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METHODS

The method of measuring the antibacterial properties of plants is essentially the same as that devised by the Oxford group (Abraham *et al.,* 1941) for assaying penicillin and since adapted to the assay of other antibiotics produced by micro-organisms. It is a method which has been used in other parts of the world to appraise medicinal plants (Pederson and Fisher, 1944; Lucas and Lewis, 1944; Sanders, Weatherwax, and McClung, 1945; Carlson *et al.,* 1946; and many others). It is based upon the assumption that an agent which acts upon a test organism to achieve a particular effect will also act upon other related organisms in a similar manner. While the assumption is not always substantiated by experimental evidence, it is tenable often enough to give the method some usefulness as a "screening test" for distinguishing agents that are "likely" to be effective from those which are "likely" to be ineffective. It is a method which has its deficiencies, certainly, but it is better than no method at all.

The plants to be studied were collected over a period of 2 years as they could be found on the island of Oahu. Most of them were obtained on or near the University of Hawaii campus and in the adjacent Manoa Valley. Whenever feasible, specimens of the complete plant—roots, stems, leaves, buds, flowers, and fruits—were obtained, either all at once or during those seasons when they could be found. In the case of a plant of which only certain portions had been used in the native pharmacopeia, we were careful to collect and to study at least those prescribed portions of the plant if not all of it. Many of the plants, or many of the parts of the different species, were tested several times during the course of our study, in several instances by each of us independently.

The specimens were taken to the laboratory soon after they were collected, and either were subjected immediately to the process of assay or were frozen and held at —10° C. until they could be studied.

Extracts of the whole plants or of certain separated portions of them—as, for example, the roots, the stems, the leaves, the flowers, the fruits, or of any indicated combinations of these—were obtained by first cutting the plant material into small pieces and by then subjecting these fragments to high pressures, ranging from 15,000 to 20,000 pounds per square inch, achieved by means of a Carver hydraulic press. No water or solvent of any kind was added to the plant material, and in almost all cases the specimens yielded ample amounts of tissue fluids for the purposes of the study.

The extracts of the different portions of the plants were kept in separate beakers, and were placed immediately in a refrigerator until the next step in the assay could be performed. In most instances the period of storage was only 1 to 2 hours; in no case was it longer than 4 hours.

Most of the extracts were assayed for their antibacterial effect upon three test strains of bacteria: *Micrococcus pyogenes* var. *aureus* (until recently known as *Staphylococcus aureus*), *Escherichia coli,* and *Pseudomonas aeruginosa.* A few of those extracts studied early in these investigations were tested against *M. pyogenes* var. *aureus* and *E. coli* only. Seventeen of the plants, which the literature described as having been employed to combat intestinal infections, were tested against five different strains of enteric pathogens as well as against the three standard cultures. The enteric pathogens used were: *Salmonella typhosa, Sal. montevideo, Sal. schottmuelleri, Shigella paradysenteriae* BH, and *Shig. paradysenteriae* III-Z. Cultures of all of these test organisms were obtained from the stock culture collection of the Department of Bacteriology, University of Hawaii.

Pure cultures of the test bacteria were grown in nutrient broth at 37° C. for 24 hours before they were used. When an assay

was about to be performed, 0.5 ml. of the broth culture of the test organism was inoculated into 100 ml. of melted nutrient agar cooled to 41° C. This heavily seeded agar medium was then poured into sterile petri dishes, about 10 ml. to a dish, and the medium was allowed to solidify at room temperature. After the medium had solidified, one or two sterile porcelain penicups were placed upon the surface of the agar.

The plant extract being tested was then placed in the appropriate penicup, 0.2 ml. of extract in each cylinder. At first extracts were tested in duplicate until, with time and the perfection of our techniques, we found that duplicate platings were unnecessary. The plates were incubated in the upright position at 37.5° C. for 24 hours, at which time they were examined for the degree of inhibition achieved by the plant extracts as they diffused into the medium from the bases of the penicups. In most of the instances in which inhibition was achieved, it was denoted by a clear halo-like zone in the medium around the penicup, with the heavy growth of uninhibited bacteria making the medium opaque around the periphery of the zone of inhibition. A few of the plant extracts produced a considerable discoloration or opacity in the medium around the penicups, but in only a very few instances did this discoloration interfere with determinations of the extracts' effects upon the test organisms.

The degree of antibacterial effect was reflected directly, of course, in the size of the zone of inhibition: the greater the zone, the more potent the extract. The diameter of the zone could be measured quite easily in most instances and was recorded, in millimeters, for each extract tested.

Several other techniques for determining the efficacy of the plant extracts were also tried—such as using filter paper discs of varying sizes soaked in the plant extract before they were applied to the inoculated agar, or actually incorporating 1 ml. of the plant extract or of varying dilutions of it into the inoculated medium before it had solidified—but the penicup method seemed to be the one which gave the most consistent and the most clear-cut results, and it was adopted for continued use.

Just before each extract was tested for its effect upon the bacteria, its *p*H was determined by means of a Macbeth line-operated *p*H meter. A series of tests was also performed to determine the inhibitory effect of H-ions and OH-ions in buffer solutions of assorted *p*H in order to ascertain whether or not the inhibitory effects of the different plant extracts might be merely a reflection of their *p*H values. The buffer solutions were prepared from tablets each of which, upon being dissolved in 100 ml. of distilled water, gave a solution of specified *p*H value.[2]

Information concerning the plants reported in this paper is presented in Table 1, which shows (1) the major plant group and the family to which each plant belongs; (2) the scientific name of the plant; (3) the common names of the plant, in both English and Hawaiian; and (4) epitomes of the usual purposes for which the plant was employed, according to the references consulted in preparing the list (the specific references are cited in the table).

We can make no claim to being taxonomists and have based our presentation of the systematic relationships of these plants upon the manner in which Neal has set them forth in her recent book *In Gardens of Hawaii* (1948). In her introduction to this compendium, Miss Neal states that she has followed the system of Engler and Prantl for the flowering plants, and the arrangement of A. J. Eames for the ferns and fern allies.

The single specimen of alga collected, *Gracilaria furcellata,* was identified by Dr. Marion L. Lohman, associate professor of botany at the University of Hawaii. Most of the

[2] The tablets are produced by the Coleman Electric Company, Maywood, Ill.

TABLE 1

SCIENTIFIC AND COMMON NAMES OF THE PLANTS TESTED, THEIR SYSTEMATIC RELATIONSHIPS, AND THE MEDICINAL USES TO WHICH THEY WERE PUT

(K & A = Kaaiakamanu and Akina, 1922; Deg. = Degener, 1930; Handy = Handy, Pukui, and Livermore, 1934; Neal = Neal, 1948)

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Gracilariaceae	*Gracilaria furcellata* Mont.	seaweed; *limu manauea* (?)	sores, skin blotches, "cure for miscarriage" (K & A: 62)
Psilotaceae	*Psilotum nudum* (L.) Griseb.	upright *Psilotum; moa*	thrush, diarrhoea in infants (Deg.: 20; Neal: 7)
Gleicheniaceae	*Dicranopteris linearis* (Burm.) Underw.	false staghorn fern; *uluhe*	laxative (Deg.: 27)
Polypodiaceae	*Nephrolepis biserrata* (Sw.) Schott.	related to Boston fern; *okupukupu*	not known (listed in Handy: 44)
	Cibotium Chamissoi Kaulf.	tree fern; *hapu*	asthma, "lung troubles" (K&A: 16)
Pandanaceae	*Freycinetia arborea* Gaud.	climbing screwpine; *ieie*	general debility, thrush, high fever (K & A: 22)
	Pandanus Rockii Mart.	a screwpine, related to the *hala* of the Hawaiians	*hala* was used for general debility, constipation, "pain in chest" (K & A: 41); asthma (personal communication)
Gramineae	*Bambusa* sp.	"small-leaved bamboo"; *ohe laulii*	ulcers and scrofulous sores (K & A: 30)
	Coix lacryma-jobi L.	Job's tears; *pu oheohe*	curative charm (Neal: 74)
	Saccharum officinarum L.	sugar cane; *ko kea*	cuts and wounds, urethritis (K & A: 6, 53); adjuvant (Handy: 21); pulmonary disease (personal communication)
	Setaria palmifolia (Willd.) Stapf	palm grass	use unknown; hearsay
	Stenotaphrum secundatum (Walt.) Ktze.	buffalo grass; *akiaki, manienie mahikihiki*	sores and ulcers on skin (K & A: 10)
Cyperaceae	*Scirpus validus* Vahl.	great bulrush; *aka'akai naku, neki*	"gripping pain of the stomach or intestines, and for intestinal hemorrhages" (K & A: 10)
Palmae	*Cocos nucifera* L.	coconut; *niu*	general debility and cuts (K & A: 73); thrush (Handy: 22)
Araceae	*Alocasia macrorrhiza* (L.) Sweet	*ape keokeo*	burns, stomach ache, aphrodisiac (K & A: 17)
	Colocasia esculenta (L.) Schott.	taro; *kalo*	laxative (K & A: 17)
Commelinaceae	*Commelina diffusa* Burm. f.	day flower; *honohono, makolokolo*	"purifying the blood" (K & A: 71)
Liliaceae	*Allium fistulosum* L.	green onion; *aka'akai*	tuberculosis, colds, and venereal diseases (K & A: 10)
	Cordyline terminalis (L.) Kunth. var *Ki* (Schott.) J. G. Baker	*ti, ki, lau'i*	asthma, congestion of lungs, high fever (K & A: 50)
Dioscoreaceae	*Dioscorea alata* L.	yam; *uhi*	high fever (K & A: 37)
Musaceae	*Musa paradisiaca* L. ssp. *sapientum* (L.) Ktze. var.	banana; *mai'a*	asthma, general debility, stomach disorders (K & A: 65–68); throat infection (personal communication)

TABLE 1 *(Continued)*

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Zingiberaceae	*Alpinia purpurata* (Vieill.) K. Schum.	red ginger	use unknown; hearsay
	Hedychium coronarium Koenig	white ginger; *awapuhi keokeo*	"for foetid nostrils" (K & A: 20)
	Zingiber Zerumbet (L.) Smith	mountain ginger; *awapuhi kuahiwi*	cuts and sores (K & A: 19)
Casuarinaceae	*Casuarina equisetifolia* L.	ironwood	astringent (Neal: 247)
Piperaceae	*Peperomia membranacea* H. & A.	peperomia; *alaalawainui*	general debility, pulmonary diseases, venereal diseases, scrofulous swellings and ulcers (K & A: 13–14)
	Peperomia latifolia Miq.	peperomia; *alaalawainui*	same as above
Moraceae	*Artocarpus incisus* (Thunb.) L. f.	breadfruit; *ulu*	skin diseases and boils (K & A: 38; Handy: 31)
	Morus alba L., f. *nigrobacca* Mold.	mulberry; *kilika*	use unknown; hearsay
Urticaceae	*Touchardia latifolia* Gaud.	*olona, wauke-malulo*	"bodily ailments or weaknesses" (K & A: 71)
Santalaceae	*Santalum album* L.	Indian sandalwood; related to the *iliahi* of the Hawaiians	*iliahi* was used for sores, venereal diseases (K & A: 24; Neal: 278)
Amaranthaceae	*Amaranthus spinosus* L.	spiny amaranth; *pokai kuku*	use unknown; hearsay
Nyctaginaceae	*Mirabilis Jalapa* L.	four o'clock; *nani ahiahi*	poultices, purgatives (Neal: 288)
Batidaceae	*Batis maritima* L.	pickleweed; *akulikuli kai*	"leaves have medicinal value" (Neal: 291)
Portulacaceae	*Portulaca oleracea* L.	pigweed; *akulikuli kula, ihi-ai, lumaha'i*	general debility (K & A: 24)
Cruciferae	*Nasturtium officinale* R. Br.	water cress; *leko*	"for dry throat and cold in the head," asthma (K & A: 64); tuberculosis (personal communication)
Crassulaceae	*Bryophyllum pinnatum* (Lam.) Kurz.	air-plant	fevers (Neal: 329)
Pittosporaceae	*Pittosporum Tobira* (Thunb.) Ait.	related to the *ho'awa* of the Hawaiians	*ho'awa* was used for sores (Neal: 335); scrofula (K & A: 44)
Rosaceae	*Rubus rosaefolius* Sm.	thimbleberry	use unknown; hearsay
Leguminosae	*Acacia confusa* Merr.	Formosa koa	use unknown; chosen for its relationship to *Acacia Koa*
	Acacia Koa Gray	*koa, kahilikolo*	general debility, diseases of the skin (K & A: 46)
	Cassia Leschenaultiana DC.	cassia; *lauki*	use unknown; hearsay
	Crotalaria incana L.	rattlebox; *pikakani*	use unknown (listed in Handy: 74)
	Crotalaria mucronata Desv.	rattlebox; *pikakani*	use unknown; hearsay
	Dioclea violacea Mart.	sea bean; *maunaloa*	cuts, skin diseases, "purifying the blood" (K & A: 65)
	Leucaena glauca (L.) Benth.	false koa; *koa haole*	use unknown; hearsay
	Medicago sativa L.	alfalfa	use unknown; hearsay
	Prosopis chilensis (Mol.) Stuntz	algaroba; *keawe*	dysentery, sore throat (Neal: 363)

TABLE 1 *(Continued)*

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
	Tamarindus indica L.	tamarind; *wi 'awa 'awa*	"used medicinally in India" (Neal: 366)
	Vigna marina (Burm.) Merr.	*nanea, okoleomakili*	general debility, asthma, boils and cuts (K & A: 33)
Rutaceae	*Citrus aurantifolia* (Christmann) Swingle	lime	use unknown; hearsay
	Pelea sp.	*alani*	general debility, "purifying the blood," skin diseases: "makes the skin immune to certain diseases" (K & A: 16)
Euphorbiaceae	*Aleurites moluccana* (L.) Willd.	candlenut tree; *kukui*	general debility, asthma, scrofulous sores, ulcers of skin (K & A: 56–57); diphtheria (personal communication)
	Euphorbia hirta L.	hairy spurge; *kokokahiki, akoko*	cathartic, gargle, poultice (Handy: 19); thrush (Deg.: 198)
	Euphorbia pulcherrima Willd.	poinsettia; *koko*	use unknown (listed in Handy: 39, 44)
	Euphorbia Milii Ch. des Moulins	crown-of-thorns	use unknown; hearsay
	Euphorbia Tirucalli L.	pencil plant	use unknown; hearsay
	Hura crepitans L.	sand-box tree	"leprosy and other conditions" (Neal: 451)
	Ricinus communis L.	castor bean; *koli, pa'aila*	fever (K & A: 55)
Anacardiaceae	*Mangifera indica* L.	mango; *manako*	astringent (Neal: 457)
	Schinus terebinthifolius Raddi	Christmas berry tree; *wilelaiki*	use unknown; hearsay
Sapindaceae	*Cardiospermum Halicacabum* L.	balloon vine, heartseed; *inalua, poniu*	rheumatism, digestive and pulmonary disorders (Neal: 467)
	Dodonaea viscosa L.	*aalii, kumakani*	rash and itch (K & A: 2)
Malvaceae	*Hibiscus tiliaceus* L.	*hau kae kae*	laxative (Neal: 49); congested chest, sore throat (K & A: 40)
	Malvastrum coromandelianum (L.) Garcke	false mallow	poultices (Neal: 485)
	Sida fallax Walp.	*ilima*	general debility, asthma, "fallen womb," laxative (K & A: 26; Neal: 485)
Sterculiaceae	*Waltheria americana* L.	*hialoa, uhaloa, kanakaloa*	asthma, sore throat, pulmonary complications (K & A: 37; Neal: 503; personal communication)
Guttiferae	*Calophyllum Inophyllum* L.	Alexandrian laurel; true *kamani*	use unknown (listed in Handy: 43; Neal: 513)
Passifloraceae	*Passiflora edulis* Sims f. *flavicarpa* Degener	yellow *lilikoi*	use unknown; hearsay
	Passiflora foetida L. var.	running pop, red passion fruit	use unknown; hearsay
	Passiflora sp.	green *lilikoi*	use unknown; hearsay
Caricaceae	*Carica Papaya* L.	papaya; *nikana, he'i*	skin diseases (Neal: 527); deep cuts (K & A: 43)
Cactaceae	*Opuntia megacantha* Salm-Dyck	prickly pear; *panini*	constipation (K & A: 73)

TABLE 1 *(Continued)*

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Thymeliaceae	*Wikstroemia oahuensis* (Gray) Rock	*akia*	laxative, asthma (K & A: 8); fish poison (Neal: 540; Deg.: 224–225)
Punicaceae	*Punica Granatum* L.	pomegranate; *pomaikalana*	used in Orient (Neal: 551)
Combretaceae	*Terminalia Catappa* L.	tropical almond; false *kamani*	"used medicinally" (Neal: 551)
Myrtaceae	*Eucalyptus* sp.	eucalyptus; *nuholani*	fevers, sores, pains, rheumatism (K & A: 73)
	Eugenia Cumini (L.) Druce	Java plum	use unknown; hearsay
	Eugenia malaccensis L.	mountain apple; *ohia ai*	general debility, thrush, sores, cuts (K & A: 31–32); throat infection (personal communication)
	Metrosideros macropus H. & A.	*ohia lehua, ohia hamau*	sore throat, bronchitis, consumption, wounds (Handy: 20)
	Psidium Guajava L.	guava; *kuawa*	"medicinal tea" (Neal: 556); deep cuts, sprains, diarrhoea, intestinal hemorrhages (K & A: 55)
Apocynaceae	*Nerium Oleander* L.	oleander; *oleana*	skin diseases (Neal: 611)
	Thevetia peruviana (Pers.) K. Schum.	be-still, yellow oleander	"used medicinally" (Neal: 610)
Convolvulaceae	*Ipomoea Batatas* (L.) Poir.	sweet potato; *uala*	medicinal uses (Handy: 21); asthma, constipation, "fallen womb" (K & A: 35–36)
	Ipomoea congesta R. Br.	morning glory; *koali awahia*	purgative, healing broken bones (Handy: 19; K & A: 52; Neal: 623); relief of muscular pain (personal communication)
	Ipomoea pes-caprae (L.) Sweet	beach morning glory; *pohuehue*	"good for the expectant mother" (K & A: 73)
Boraginaceae	*Messerschmidia argentea* (L. f.) Johnston	tree heliotrope; *tahinu*	use unknown; hearsay
Verbenaceae	*Lantana Camara* L.	lantana; *lakana*	use unknown; hearsay
	Stachytarpheta cayennensis (L. C. Rich.) Vahl.	vervain; *oi*	"used in tropical America" (Neal: 639)
Solanaceae	*Capsicum frutescens* L.	red pepper; *nioi*	pains in back, rheumatism, swollen feet (K & A: 72)
	Lycopersicon esculentum Mill. ssp. *Galeni* (Mill.) Luckwill	currant tomato; *ohia makanahele*	use unknown; hearsay
	Solanum nodiflorum Jacq.	black nightshade; *popolo*	disorders of respiratory tract, skin eruptions, cuts, wounds (Handy: 18; Neal: 655); trachoma (personal communication)
	Solanum sodomaeum L.	apple of Sodom; *popolo kikania*	used in Africa for skin diseases (Neal: 655)

TABLE 1 *(Continued)*

FAMILY	SCIENTIFIC NAME OF SPECIES	COMMON NAMES IN HAWAII	TRADITIONAL USES AS MATERIA MEDICA
Plantaginaceae	*Plantago lanceolata* L.	narrow-leaved plantain; *laukahi*	sores or boils (Handy: 21); general debility, constipation, boils (K & A: 58); diabetes and "to clear the system" (Neal: 695)
	Plantago major L.	broad-leaved plantain; *laukahi*	same as above
Rubiaceae	*Morinda citrifolia* L.	Indian mulberry; *noni*	broken bones, deep cuts (K & A: 73); cuts, bruises, sores, wounds (Handy: 18)
Cucurbitaceae	*Momordica Charantia* L.	bitter melon, balsam pear	used in the preparation of a Japanese remedy for skin ailments, headache, constipation (Neal: 709)
Goodeniaceae	*Scaevola frutescens* (Mill.) Krause var. *sericea* (Forst. f.) Merr.	beach naupaka; *naupaka kahakai*	"used medicinally in Malaya" (Neal: 720); cuts and skin diseases (K & A: 72)
	Scaevola Gaudichaudiana Cham.	mountain naupaka; *naupaka kuahiwi*	same as above
Compositae	*Bidens pilosa* L.	beggar tick; related to the *ko'oko'olau* of the Hawaiians	"used medicinally" (Neal: 742)
	Erigeron albidus (Willd.) Gray	related to Canada fleabane; *iliohe*	"used medicinally in Java" (Neal: 733; listed in Handy: 42)

plants were identified for us by Dr. Harold St. John, professor of botany and chairman of the Department of Botany at the University of Hawaii. We are grateful for their help and their encouraging interest in these studies. At Dr. St. John's suggestion, herbarium specimens of the plants studied were prepared by us and are preserved in the Department of Bacteriology at the University of Hawaii.

DATA AND DISCUSSION

We are well aware of the shortcomings of this approach to an appraisal of the medicinal plants found in Hawaii, if only because so many of these plants were not used primarily for their effect against bacteria: they were used as cathartics, vermifuges, emollients, astringents, analgesics, counterirritants, and other salutaries, as well as for their action in preventing infection and for treating an infection once it had begun. We know, too, that studying the effects of these plants upon bacteria *in vitro* does not test them under the conditions *in vivo* in which they were intended to be used: there are so many factors involved in the living body which might contribute important assistance to the medicinal agent when it is properly applied by the herbalist. The purists among admirers of the *kahuna's* lore will also point out that we did not use the ancient prescriptions exactly as they were applied by the *kahuna.* To this our answer must be that, in this initial stage of the investigation, we were concerned with studying the effects of the component parts of the prescriptions, hoping that later, when we had found all of the components, we could put them together to see if they are any more effective when they are used concurrently than when they are used alone.

The number of kinds of plants available

for study was limited, too. Many of those which played an important part in the *kahuna's* pharmacy were difficult to obtain even in their day, and are even harder to find now. Some of them have become extinct or inaccessible, and most of the plants grow in habitats so far removed from the laboratory that they are not conveniently available for study.

The number of species of bacteria we could use to determine the "spectrum" of activity of a plant—that is, the range of its effectiveness as an antagonistic agent for the different species of bacteria— was so limited by the time and facilities at our disposition that we could not possibly expose all of the different micro-organisms which might have assailed a susceptible Hawaiian.

Nonetheless, the determination of the antibacterial effect of extracts of the different medicinal plants offers the one feasible means for assaying them in the absence of human cases to study or of laboratory animals to experiment upon.

Before very many plants were tested it became evident that there were great variations in effectiveness of the plant extracts obtained from the different species of plants, and, indeed, often among extracts obtained from the several parts of the same plant. There was also considerable variation in effectiveness of many of the extracts against the several different test organisms.

It is difficult, then, to tabulate easily the results obtained in this study. We have finally decided to do what the Hawaiians did, and to treat each separate part of a plant as an entity of its own—if only because we found, as they did, that the different parts of the plant vary astonishingly in their pharmacological properties.

We set some arbitrary standards of efficacy, basing these standards upon the Oxford group's definition of a unit of penicillin—that amount of penicillin which gives an inhibition zone 24 mm. in diameter—and the work of Sanders *et al.* (1945) in appraising the antibacterial substances in plants collected in Indiana. Four categories were established, based upon the diameters of the zones of inhibition obtained with the plant extracts *against any one of the test organisms:*

1. Very effective: zones more than 20 mm. in diameter
2. Moderately effective: zones between 10 and 20 mm. in diameter
3. Slightly effective: zones less than 10 mm. in diameter
4. Ineffective: no apparent zone of inhibition

The summarized data of our studies are presented in Tables 2–6 and in a simple listing of the ineffective extracts (see p. 179). Table 2 presents the results of the studies with buffer solutions of different *p*H values. Tables

TABLE 2

EFFECT OF BUFFER SOLUTIONS OF DIFFERENT *p*H UPON THE TEST BACTERIA

TEST ORGANISMS	ZONES OF INHIBITION (IN MM.) ACHIEVED BY 0.2 ML. OF BUFFER SOLUTIONS		
	*p*H 3.0	*p*H 4.0	*p*H 5.0, 6.0, 8.0
Micrococcus pyogenes var. *aureus*	10	0	0
Escherichia coli	10	8	0
Pseudomonas aeruginosa	12	8	0
Salmonella typhosa	8	0	0
Salmonella montevideo	10	0	0
Salmonella schottmuelleri	12	8	0
Shigella paradysenteriae BH	13	0	0
Shigella paradysenteriae III-Z	13	0	0

3–6 are concerned with the antibacterial effects of the plant extracts and present this information: (1) the scientific name of the plant; (2) the part of the plant yielding the extract being tested; (3) the *p*H of the extract; and (4) the diameters of the zones of inhibition, measured in millimeters, developed against the different test organisms. Wherever, by intention or by accident, a particular bit of information was not obtained, a question mark (?) indicates this fact; the words "not tested" mean that the organism (usually *Ps. aeruginosa*) was not used in the testing of a particular extract; the symbol "qns" means "quantity not sufficient" to obtain a *p*H determination; the symbol "O" means no apparent zone of inhibition.

The tests showed that very acid buffer solutions (*p*H 3.0 and 4.0) are only moderately effective in their ability to inhibit growth of the test organisms, and that solutions with *p*H values ranging from 5.0 to 8.0 had no effect at all.

This is an observation that has direct bearing upon the results disclosed in this study of extracts from Hawaiian medicinal plants, for, in a number of instances—as will be seen from Tables 3 to 6—it was found that the zones of inhibition produced by the extracts were far greater than were the zones of inhibition produced by the buffer solutions having the same *p*H values as did the extracts being tested. In those extracts having a *p*H more acid than 3.0, moreover, the degree of inhibition achieved by the extracts was significantly greater than that achieved by the buffer solution of *p*H 3.0. On the other hand, as the list on page 179 shows, there were also many extracts of moderate acidity which exerted no inhibitory effect at all upon the test bacteria.

The implication here is that, in those plant extracts which are potent in their degree of inhibition of the test bacteria, it is not so much the mere *p*H of the extract that is the effective antibacterial agent, but rather the

TABLE 3
EXTRACTS WHICH EXHIBIT VERY EFFECTIVE ANTIBACTERIAL PROPERTIES
(with zone of inhibition 20 mm. or more in diameter)

NAME OF PLANT	PART OF PLANT PROVIDING EXTRACT	*p*H OF EXTRACT	DIAMETER OF ZONES OF INHIBITION (IN MM.)		
			M. pyogenes	*E. coli*	*Ps. aeruginosa*
Dicranopteris linearis	leaves and stems	4.6	21	0	13
Alpinia purpurata	leaves	6.6	10	22	20
Acacia Koa	stems	5.6	20	0	0
Tamarindus indica	ripe fruit	2.4	30	30	not tested
	fruit, aqueous extract	?	25	24	not tested
	green fruit	2.5	25	26	25
Citrus aurantifolia	fruit	2.6	27	25	25
Hura crepitans	flowers	4.5	20	14	(discolored)
Passiflora edulis f. *flavicarpa*	green fruit	3.4	27	28	30
	ripe fruit	3.7	22	22	20
Passiflora foetida var.	fruit	4.2	15	32	15
Passiflora sp.	flowers	5.6	10	35	10
Punica Granatum	whole fruit*	3.5	20	20	15
	fruit-rind	3.7	22	0	13
Eugenia malaccensis	seeds	4.7	25	0	0
	bark*	5.9	20	0	not tested
	leaves*	5.4	20	0	not tested
Metrosideros macropus	stems	4.9	30	8	8
Psidium Guajava	leaves and flowers	?	20	10	not tested

* See Table 6.

TABLE 4

EXTRACTS WHICH EXHIBIT MODERATELY EFFECTIVE ANTIBACTERIAL PROPERTIES
(with zones of inhibition between 10 and 20 mm. in diameter)

NAME OF PLANT	PART OF PLANT PROVIDING EXTRACT	*p*H OF EXTRACT	DIAMETER OF ZONES OF INHIBITION (IN MM.) *M. pyogenes*	*E. coli*	*Ps. aeruginosa*
Psilotum nudum	whole plant	5.2	15	0	8
Nephrolepis biserrata	stems	5.1	12	0	0
Cibotium Chamissoi	leaflets	4.6	14	15	12
	buds (of leaves)	5.2	10	0	8
Freycinetia arborea	stems	5.8	11	0	0
Allium fistulosum	whole plant	4.3	10	8	10
Alpinia purpurata	stem	5.9	10	12	15
Artocarpus incisus	male and female flowers	6.3	0	11	not tested
Bryophyllum pinnatum	bark	5.2	0	8	10
	leaf	4.8	0	8	10
Acacia Koa	true leaves	5.5	13	0	0
	phyllodes	5.6	16	0	0
Tamarindus indica	leaves and stems	3.8	12	0	not tested
Aleurites moluccana	leaves and stems	5.8	10	0	0
	flowers	5.0	10	0	0
	leaves only	6.4	10	0	0
Euphorbia pulcherrima	floral parts	5.1	0	0	12
	leaves and stems	5.5	0	0	12
Euphorbia Milii	leaves	4.9	10	0	0
	stems	5.6	10	0	0
Euphorbia Tirucalli	stems	4.5	15	8	8
Mangifera indica	leaves	5.2	12	? (discolored)	not tested
	bark and stems	4.8	11	? (discolored)	not tested
	fruit, small, green	3.5	18	16	not tested
	fruit, half-ripe	3.2	13	15	9
Passiflora sp.	leaves and stems	6.1	12	10	0
Punica Granatum	fruit, seeds*	3.8	14	0	11
Terminalia Catappa	leaves and stems	4.8	18	0	0
Eucalyptus sp.	leaves and stems	4.8	13	0	0
Eugenia Cumini	leaves	5.0	17	12	0
	stems	5.0	15	0	0
	buds and flowers	4.5	15	0	0
Eugenia malaccensis	leaves*	3.4	12	11	11
	fruits (without seed)	4.5	14	18	0
Metrosideros macropus	leaves and buds	4.3	18	17	18
Psidium Guajava	fruit*	3.5	18	16	not tested
Ipomoea Batatas	stem	6.7	18	0	not tested
Solanum nodiflorum	green fruit	4.6	0	0	10
	ripe fruit*	4.7	0	0	18
	leaves and stems	5.8	10	10	0
Solanum sodomaeum	leaves	5.6	10	0	0
	stems	5.6	10	0	0
	fruits	5.1	10	0	0
Plantago major	whole plant*	5.5	11	10	not tested
Morinda citrifolia	ripe fruit*	4.4	15	10	15
Scaevola Gaudichaudiana	stems	5.9	16	0	0
	fruits and flowers	5.7	13	0	0
Bidens pilosa	whole plant*	5.8	15	15	12

* See Table 6.

nature of the substances which are present in the plant juices. In other words, and as herbalists and pharmaceutists long ago realized, it is the possession of chemical properties peculiar to itself that makes a plant different from its neighbors and superior to some of them for use as a medicine. The medicinal plants in Hawaii are no exception to this obvious rule. We are not able to say what substances in the tissues of the more effective of the Hawaiian plants are responsible for their efficacy.

The results of the tests with the actual extracts show that of the 101 species studied, 13 possess a considerable degree of effectiveness against the test bacteria (Table 3). Four of these plants—*koa, Acacia Koa;* mountain apple, *Eugenia malaccensis; ohia lehua, Metrosideros macropus*; and guava, *Psidium Guajava*—the Hawaiians have employed in the treatment of cuts and wounds and "skin diseases," or of bacterial infections like "diarrhoeas and dysenteries," but most of the others are plants which do not appear to have played much of a part in the treatment of conditions caused by bacteria. Most of them—*Alpinia purpurata, Tamarindus indica, Citrus aurantifolia, Hura crepitans,* the three *Passiflora* species, and *Punica Granatum*—do not seem to have been used at all by the Hawaiians, possibly because of their relatively recent introduction into Hawaii. One plant, the *uluhe, Dicranopteris linearis,* was used by the Hawaiians as a laxative, but not, as far as we know, in the treatment of conditions in which bacteria were implicated as the causative agents. All of these plants are worthy of further study to see if it is possible to obtain from any of them a useful antibacterial substance.

An even greater number of plant species is moderately effective in the action against the test bacteria (Table 4). Among these are several of the more famous and the more favored of the Hawaiian remedies: the *kukui, Aleurites moluccana*; the *popolo, Solanum nodiflorum*; the *noni, Morinda citrifolia*; the *laukahi, Plantago major*; and *Bidens pilosa,* a relative of the native "tea," *ko'oko'olau.* All of these plants had a great number of uses in Hawaiian medicine, and the *popolo* in particular has been called "ke kumu o ka lapaau o Hawaii nei"—"the foundation of Hawaiian pharmacy" (Handy *et al.,* 1934: 18). The juices of its leaves and berries were used, either alone or in combination with other ingredients, for diseases of the skin, in the treatment of cuts and wounds, in "disorders of the respiratory tract," and for "toning up the digestive tract" (Handy *et al., loc. cit.*).

Our studies showed that each of the favor-

TABLE 5
EXTRACTS WHICH EXHIBIT SLIGHTLY EFFECTIVE ANTIBACTERIAL PROPERTIES
(with zones of inhibition less than 10 mm. in diameter)

NAME OF PLANT	PART OF PLANT PROVIDING EXTRACT	*p*H OF EXTRACT	DIAMETER OF ZONES OF INHIBITION		
			M. pyogenes	*E. coli*	*Ps. aeruginosa*
Cibotium Chamissoi	stems of fronds	5.1	0	0	8
Bambusa sp.	leaves and stems	qns	7	0	0
Peperomia latifolia	whole plant	5.7	0	0	8
Pittosporum Tobira	bark*	6.2	0	0	8
	leaf*	6.1	0	0	9
Sida fallax	stems	6.2	9	0	0
Waltheria americana	water extract of leaves and stems	5.5	0	0	8
Eugenia malaccensis	stems	4.3	8	0	0
Lantana Camara	leaf	7.3	8	0	not tested

* See Table 6.

ite plants listed in Table 4 exerts some effect, at least *in vitro,* against representatives of bacterial agents of disease. Perhaps, as the users of these simples were daring enough to learn, they are even more effective when they are applied to the diseased body, when the body can contribute the weapons in its own armory to the attack upon the invading bacteria. Perhaps, too, when they are compounded with other herbs in the complex recipes which many of the *kahunas* prescribed, the total effect of the combination of ingredients is superior to the effect of each of the recipes' components.

Here is one of the simpler prescriptions, taken from the wonderfully naïve herbal of Kaaiakamanu and Akina (1922: 57):

"For scrofulous sores, bad cases of ulcer, and other bad sores where the flesh seems to rot away, the following mixture is recommended: Take the meat of eight *kukui* nuts and have it baked in *ki* leaves until thoroughly cooked. This is pounded or finely ground and then set to one side. About a tablespoonful of the breadfruit milk is then secured and mixed with the prepared *kukui* meat. In the meantime about a spoonful of the finely ground *Cyperus laevigata* fibers [*ahuawa*] and a like amount of the *lama* powder [*Maba* spp.] are being thoroughly mixed. The two mixtures are then put together and thoroughly stirred and applied by spreading it [*sic*] over the sore or sores. This is done morning and evening and as long as necessary.

"Before the treatment, however, the sore should be washed with the tea of the *Bobea* spp. bark [*ahakea*] thoroughly cooked with about a gallon of water and with four red hot stones. The bark should be pounded before boiling it in order to get its strength."

Table 5 gives the information concerning the relatively few plant extracts which were only slightly effective against the test bacteria. A few of them are extracts from parts of plants which, in others of their parts, are much more effective against the test bacteria, but most of them are examples of mediocrity in performance that would sadden the heart of a *kahuna lapaau.*

The following extracts exhibited no apparent antibacterial properties: *Gracilaria furcellata* (whole plant, 5.9[3]); *Psilotum nudum* (tea, 5.2); *Nephrolepis biserrata* (leaves, 5.3); *Freycinetia arborea* (leaves, 5.9); *Pandanus Rockii* (ripe fruit, 5.1); *Coix lacryma-jobi* (whole plant, 5.6); *Saccharum officinarum* (leaves, 5.4; stems, 5.1); *Setaria palmifolia* (whole plant, 6.0); *Stenotaphrum secundatum* (leaves, 6.1; stems and roots, 6.0); *Scirpus validus* (whole plant, 6.7); *Cocos nucifera* (milk from nut, 6.7); *Alocasia macrorrhiza* (leaves, 6.0; stems, 5.8; corms and roots, 5.8); *Colocasia esculenta* (corm, 7.0); *Commelina diffusa* (whole plant, 5.4); *Cordyline terminalis* var. *Ki* (leaves and stems, 5.8); *Dioscorea alata* (tuber, 5.7); *Musa paradisiaca* ssp. *sapientum* var. (stem, 5.7; leaf, 6.2; flower bud, 5.0); *Hedychium coronarium* (roots, 6.4; leaves and stems, 6.1; buds and flowers, 6.1); *Zingiber Zerumbet* (root, 6.0; leaves and stems, 5.8; buds and flower-stalks, 6.0); *Casuarina equisetifolia* (leaves and stems, 5.1; cones, 4.5; alcoholic extract of leaves and stems, ?); *Peperomia membranacea* (whole plant, 6.0); *Artocarpus incisus* (leaves and stems, 6.2); *Morus alba* f. *nigrobacca* (leaves and stems, 6.3); *Touchardia latifolia* (bark, 6.0; stems, 6.2; leaves, 6.8); *Santalum album* (leaves and stems, 6.0); *Amaranthus spinosus* (whole plant, 6.2); *Mirabilis Jalapa* (leaves, stems, and flowers, ?; aqueous solution of seed-powder, ?); *Batis maritima* (whole plant, 5.5); *Portulaca oleracea* (whole plant, 4.5); *Nasturtium officinale* (whole plant, 4.7); *Rubus rosaefolius* (leaves and stems, 6.4); *Acacia confusa* (leaves, stems, and flowers, 5.5); *Cassia Leschenaultiana* (whole plant, 5.8);

[3]Figures in the parentheses indicate the *p*H of the respective extracts.

Crotalaria incana (leaves and stems, 5.9; seeds and pods, 5.9); *Crotalaria mucronata* (whole plant, 6.4); *Dioclea violacea* (leaf, 5.7; seed, 6.2); *Leucaena glauca* (pods, flowers, leaves, and stems, ?); *Medicago sativa* (leaves, stems, and flowers, 5.6); *Prosopis chilensis* (leaves and stems, 5.5; pods and leaves, 5.6); *Vigna marina* (whole plant, 6.0); *Pelea* sp. (leaf, 5.7); *Aleurites moluccana* (young nuts, raw, 6.3); *Euphorbia hirta* (whole plant, 5.6); *Hura crepitans* (leaves and stems, 5.2); *Ricinus communis* (leaves, 6.0; stems, 5.4; seeds, 5.9); *Mangifera indica* (fruit, ripe, 4.7); *Schinus terebinthifolius* (leaves, 4.7; berries, 5.2); *Cardiospermum Halicacabum* (leaves and stems, 6.0; fruits, 5.7); *Dodonaea viscosa* (leaves, 5.5); *Hibiscus tiliaceus* (leaves and stems, 6.2); *Malvastrum coromandelianum* (whole plant, 5.5); *Sida fallax* (leaves, ?); *Waltheria americana* (leaves and flowers, 5.5; stems, 5.5; roots, 5.8); *Calophyllum Inophyllum* (leaves, 4.8; flowers, 4.1; fruits, 5.0); *Passiflora edulis* f. *flavicarpa* (leaves and stems, 5.8); *Passiflora foetida* var. (leaves and stems, 5.5); *Carica Papaya* (leaves, 6.1; flowers, 6.2; fruit, 5.8; seeds, 5.9); *Opuntia megacantha* (leaf-pads, 4.3); *Wikstroemia oahuensis* (leaves, 6.0; stems, 6.1); *Nerium Oleander* (leaves and stems, 5.6; flowers and pods, 5.3); *Thevetia peruviana* (flowers, 6.7; leaves, 6.0; fruits, 7.1); *Ipomoea Batatas* (leaves, 7.1); *Ipomoea congesta* (whole plant, 5.5); *Ipomoea pes-caprae* (leaves and stems, 6.1; flowers and buds, 5.9); *Messerschmidia argentea* (leaves and stems, 6.0; fruits, 6.5); *Stachytarpheta cayennensis* (leaves, 6.1; stems, 6.0); *Capsicum frutescens* (leaves and stems, 5.8; tea from pods, 6.8); *Lycopersicon esculentum* ssp. *Galeni* (leaves and stems, 5.8; fruits, 4.5); *Plantago lanceolata* (whole plant, 5.5); *Morinda citrifolia* (leaves and stems, 5.1); *Momordica Charantia* (leaves, 7.3); *Scaevola frutescens* var. *sericea* (leaves and stems, 6.2; ripe fruit, 5.5); *Scaevola Gaudichaudiana* (leaves, 5.9); *Erigeron albidus* (whole plant, 5.7).

The text listing on page 179 is significant chiefly for its length. In it are included some of the species of plants which the Hawaiians often employed to treat conditions which we now recognize as bacterial infections. Among these plants are sugar cane, *Saccharum officinarum*; buffalo grass, *Stenotaphrum secundatum; awapuhi, Zingiber Zerumbet; ala-alawainui, Peperomia* spp.; *alani, Pelea* sp.; *aalii, Dodonaea viscosa; uhaloa, Waltheria americana;* the poisonous *akia, Wikstroemia oahuensis;* the deadly oleanders, *Nerium Oleander* and *Thevetia peruviana;* sweet potato and the *koali* of several kinds, *Ipomoea* spp.; chili pepper, *Capsicum frutescens; naupaka, Scaevola* spp.; and many others, but, it must be pointed out, there are also included in the list a number of species of plants which were applied by the Hawaiians to the treatment of conditions other than those caused by bacteria. It is worthy of note that, in general, the *p*H values of the extracts of these plants are significantly higher (that is, less acid) than are the *p*H values of the more effective plant extracts listed in Tables 3 and 4.

Nevertheless, this list is one of disappointments, from the bacteriologists' point of view, and reveals the price of empiricism in medicine—many failures for every success.

Table 6 is in the nature of an appendix to Tables 3 to 5. It presents the effects of extracts from 17 different plants upon the 5 strains of pathogenic intestinal bacilli used in these studies. Four of the plants were very effective in their antibacterial action and might well be studied further. Only one of these, the guava, *Psidium Guajava,* was used by the Hawaiians specifically for its curative value in "diarrhoeas and intestinal hemorrhages" (Kaaiakamanu and Akina, 1922: 55). This illustrates the ability of the Hawaiian to exploit newly introduced plants for his medicinal needs, for the guava was not brought to Hawaii until early in the nineteenth century, when Don Marin im-

TABLE 6
ACTION OF CERTAIN PLANT EXTRACTS UPON FIVE ENTERIC PATHOGENS*

ACTION	NAME OF PLANT	PART OF PLANT	*p*H OF EXTRACT	ZONE OF INHIBITION (IN MM.)				
				Salmonella typhosa	*Salmonella montevideo*	*Salmonella schottmuelleri*	*Shigella paradys.* BH	*Shigella paradys.* III-Z
VERY EFFECTIVE	*Punica Granatum*	whole fruit	3.5	20	18	27	17	12
	Eugenia malaccensis	bark	5.9	0	0	0	20	20
		leaves	5.4	0	0	0	30	35
MODERATELY EFFECTIVE	*Psidium Guajava*	fruit	3.5	20	19	18	22	30
	Morinda citrifolia	ripe fruit	4.4	23	10	12	22	20
		young fruit	5.2	10	0	0	15	15
	Momordica Charantia	leaves	7.3	8	0	0	12	12
	Bidens pilosa	whole plant	5.8	17	8	8	8	8
SLIGHTLY EFFECTIVE	*Pittosporum Tobira*	bark	6.2	10	8	0	8	8
		leaves	6.1	8	8	0	8	8
	Solanum nodiflorum	ripe fruit	6.2	8	8	8	8	8
	Plantago major	whole fruit	7.0	8	7	9	8	8

*The following extracts were found to be ineffective against the enteric pathogens: *Colocasia esculenta* (corm, 7.0); *Commelina diffusa* (whole plant, 5.4); *Dioscorea alata* (tuber, 5.7); *Musa paradisiaca* ssp. *sapientum* var. (stems, 5.7; leaves. 6.2; flower bud, 5.0); *Pelea* sp. (leaves, 5.7); *Schinus terebinthifolius* (leaves, 4.7; berries, 5.2); *Dodonaea viscosa* (leaves, 5.5); *Psidium Guajava* (leaves and flowers, ?); *Ipomoea congesta* (whole plant, 5.5); *Morinda citrifolia* (leaves and stems, 5.1).

ported it (Neal, 1948: 555). (It could not have come too soon for the dying Hawaiian race, for by this time the bloody fluxes, introduced by almost every vessel calling at Hawaii, had long since begun to take their toll of native lives, and the surviving Hawaiians must have been seeking desperately for remedies against them.)

It is possible that many of the other plants which were not tested for their action upon these enteric pathogens will possess properties antagonistic to them. A minor but interesting phenomenon is the apparent selective action of some of these plant extracts upon some of the intestinal pathogens: the action of *Eugenia malaccensis,* for example, is directed against the two *Shigella* strains only; and the young fruit of the *noni, Morinda citrifolia,* also exhibits its peculiar selectivity for the two *Shigella* strains and the typhoid bacillus.

Most of the plant extracts listed on page 179, far from inhibiting the test bacteria, markedly stimulated their growth. Many of the plant extracts which showed some degree of effectiveness against the test bacteria also stimulated the growth of the bacteria in those areas around and beyond the periphery of the zones of inhibition. This action probably can be attributed to the presence of foodstuffs and of growth-promoting factors in the extracts, even in those extracts which also possess agents which are antagonistic to the bacteria. It is also possible that, as is known to be the case with many substances, the same agent in a plant extract may be inhibitory, or even bactericidal, in high concentrations and stimulating in low concentrations.

It must be remembered, too, that the efficacy of these extracts is dependent to a considerable extent upon the diffusability of their component parts. It is, therefore, highly probable that other results might be obtained if other methods of assay were employed, or that many more of the plants might be shown to have a greater degree of effectiveness

against the bacteria if their extracts were treated in such a manner as to purify or to concentrate the antagonistic agents.

In those few instances in which subcultures were taken from the zones of inhibition, the effect of the plant extracts seemed to be a bactericidal one. This claim cannot be made for all the effective extracts inasmuch as we did not prepare subcultures from all the zones of inhibition.

It should be stated here that the studies reported in this paper are merely preliminary investigations into the effectiveness *in vitro* of extracts of plants represented in the Hawaiian pharmacopeia. They are in no sense an endorsement of the *kahuna lapaau laau's* methods or a recommendation of some of these plants for popular usage today. Neither are they to be construed as a defamation of the medical folklore of Hawaii. They are merely a search for facts, upon which some day a scientific appraisal of the Hawaiian's medicines can be based, and out of which, perhaps, a useful therapeutic may emerge.

SUMMARY

Preliminary investigations into the antibacterial properties of extracts from different portions of 101 species of plants which have been used in Hawaii for various medicinal purposes showed that extracts from 13 species possessed agents which were very effective *in vitro* in their action against test strains of *Micrococcus pyogenes* var. *aureus, Escherichia coli,* and *Pseudomonas aeruginosa.* Extracts from 30 species of plants (some of the extracts being obtained from parts of the same plants other parts of which exhibited very effective antibacterial action) possessed agents which were moderately effective. The rest were either ineffective or only slightly effective in their action. Determinations of effectiveness were made by testing extracts by the Oxford cup method developed for the assay of penicillin. Extracts were obtained by submitting freshly collected plant material to pressures of 15,000 to 20,000 pounds per square inch, achieved by means of a Carver hydraulic press.

Extracts obtained from the following plants were the most effective: *uluhe, Dicranopteris linearis*; red ginger, *Alpinia purpurata; koa, Acacia Koa;* tamarind, *Tamarindus indica*; lime, *Citrus aurantifolia*; sand-box, *Hura crepitans*; three species of passion fruit, *Passiflora edulis* f. *flavicarpa, P. foetida* var., and *Passiflora* sp.; pomegranate, *Punica Granatum*; mountain apple or *ohia ai, Eugenia malaccensis; ohia lehua, Metrosideros macropus*; and guava, *Psidium Guajava.*

Extracts of 17 of the plants were studied for their effect upon 5 strains of pathogenic enteric bacilli (*Salmonella typhosa, Sal. montevideo, Sal. schottmuelleri,* and two serological types of *Shigella paradysenteriae*). Extracts from four plants—*Punica Granatum, Eugenia malaccensis, Psidium Guajava,* and *Morinda citrifolia*—appear to possess agents which are effective against some or all of the intestinal pathogens tested.

Of the plant families studied, species of the Punicaceae, Passifloraceae, Euphorbiaceae, and Myrtaceae appear to be most effective in their antibacterial action, and invite further investigation both for themselves and for other species included in these families.

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